Emission standards for light and heavy road vehicles

Introduction

Between 1990 and 2009, greenhouse gas emissions from road traffic within the EU increased by 27 per cent, rising from 12 to 17 per cent of total EU emissions (16 to 22 per cent excluding international bunkers).[1] Emissions of most other air pollutants have decreased since 1990, but many cities still exceed the concentration limits set by the EU legislation.[2] To overcome the emission problems caused by road traffic there are two main approaches, both of which are necessary: to reduce the total amount of road traffic and to reduce emissions from individual vehicles. Common emission requirements for vehicles are an important tool for the latter.

Emission requirements for light road vehicles have existed in the EU since the early 1970s, while the first requirements for heavy vehicles came in at the end of the 1980s. Requirements have been repeatedly tightened over the years, a process that is ongoing. Today, vehicle emissions are controlled under two basic frameworks: the "Euro standards" and the regulation on carbon dioxide emissions.

The "Euro standards" regulate emissions of nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), and particle numbers (PN). There are separate regulations for light vehicles (under 3.5 tonnes) and heavy-duty vehicles. The standards for both light and heavy vehicles are designated "Euro" and followed by a number (usually Arabic numerals for light vehicles: Euro 1, 2, 3..., and Roman numerals for heavy vehicles: Euro I, II, III...). Compliance is determined by running the vehicle or the engine in a standardised test cycle. Non-compliant vehicles cannot be sold in the EU, but new standards do not apply to vehicles already on the roads. Euro standards also exist for two and three-wheeled vehicles (motorcycles and mopeds) and for engines for non-road machinery, but these are not covered here.

1 Laying the foundations for greener transport. TERM 2011: Transport indicators tracking progress towards environmental targets in Europe, EEA Report No 7/2011 *http://www.eea.europa.eu/publications/foundations-for-greener-transport* and EU Energy and transport in figures Statistical pocketbook 2010 *http://ec.europa.eu/energy/publications/statistics/statistics_en.htm*

2 Air quality in Europe – 2011 report. EEA Technical report No. 12/2011.

The regulation on carbon dioxide (CO_2) emissions is more recent and so far only covers passenger cars and vans. There are as yet no limits for CO_2 emissions from heavy-duty vehicles. The carbon dioxide directive differs from the Euro standard in that compliance is not required for a single vehicle but for the weighted performance of the entire fleet produced by a manufacturer (or a group of manufacturers) in a year.

Test cycles

Emissions are measured using a standardised test cycle that is designed to simulate real driving. For light vehicles the entire vehicle is tested and emissions are measured in grams per kilometre (g/km). For heavy vehicles the engine is bench-tested and the results are expressed in relation to the engine power, as grams per kilowatt-hour (g/kWh). A vehicle or engine that is tested and approved in one EU country may then be sold throughout the union without any requirement for further testing.

Light vehicles are subjected to a transient cycle (ECE+EUDC) in which the vehicle follows a prescribed driving pattern that includes accelerations, decelerations, changes of speed and load, etc. The first part of the cycle simulates urban driving with a maximum speed of 50 km/h, while the second part simulates motorway driving with a maximum speed of 120 km/h.

In the case of heavy vehicles both a transient cycle and a stationary cycle are used. The two cycles that have been used since 2000 are the European Stationary Cycle (ESC), which consists of a sequence of

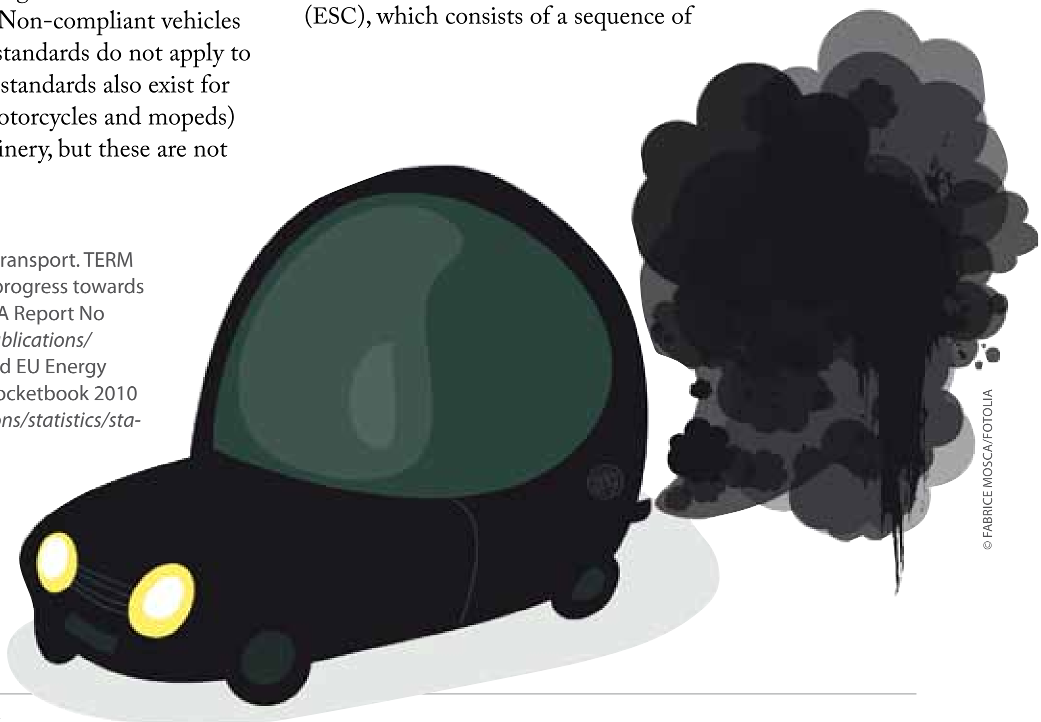

Table 1. Emission standards for passenger cars in mg/km.

	NOx		THC [1]		THC [1] + NOx		PM		PN [2]	
	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol
Euro 1 1992.07	-	-	-	-	970	970	140	-	-	-
Euro 2 1996.01	-	-	-	-	700/900 [3]	500	80-100	-	-	-
Euro 3 2000.01	500	150	-	200	560	-	50	-	-	-
Euro 4 2005.01	250	80	-	100	300	-	25	-	-	-
Euro 5a 2009.09	180	60	-	100	230	-	5	5	-	-
Euro 5b 2011.09	180	60	-	100	230	-	5	5	$6x10^{11}$	-
Euro 6 2014.09	80	60	-	100	170	-	5	5	$6x10^{11}$	-

[1] THC = Total hydrocarbons
[2] Particle number is expressed as the maximum allowed number of particles per kilometre (#/km).
[3] Indirect Injection (IDI) and Direct Injection (DI) engines respectively.

constant engine speed and load modes, and the European Transient Cycle (ETC), which simulates typical driving patterns (2005/55/EC). As from 2013 the World Harmonised Transient Cycle (WHTC) and the World Harmonised Stationary Cycle (WHSC) will replace these. The two new cycles are developed by a United Nations body known as the UN ECE GRPE to simplify registration of a new model in several parts of the world.

One dilemma with test cycles is that they never can totally simulate true driving. Cars will be designed to have low emissions in the test, but how they perform on the road can be a different story. However over the years the test cycles have gradually improved and this is not such a great problem as it used to be. It is also worth noting that car models are tested without any extra equipment. When air conditioners and music systems are in use emissions can be significantly higher.

Euro standards for light vehicles

The light category of vehicles covers road vehicles under 3.5 tonnes, i.e. both passenger cars and light commercial vehicles such as vans. Standards vary depending on whether the vehicle uses petrol or diesel, as well as on the class of the vehicle within the broader light-duty vehicle category.

The first Euro standard, Euro 1 (91/441/EEC) entered into force in 1992-93, and these requirements forced manufacturers to install three-way catalytic converters in petrol vehicles. Since then, the emissions limits have been progressively tightened, and the standards have subsequently been updated several times.

Most recently, a regulation adopted in December 2006 (715/2007/EC) established the currently applicable Euro standards. The Euro 5 standard applies to the approval of new vehicles as of September 2009, and to the sale of all new vehicles as from January 2011, while the Euro 6 standard will apply from September 2014 (new approvals) and September 2015 (all sales) onwards.

Table 1 shows the evolving standards for passenger cars for the substances of main concern. The standards for light vehicles are defined by driving distance, and expressed in milligrams per kilometre (mg/km). The limit values for light commercial vehicles are generally slightly higher than for passenger cars and are dependent on the weight class – the heavier the vehicle, the higher the permissible emissions.

As shown in Table 1, the main effect of the Euro 5 standard has been to reduce the amount of particulate matter (PM) emitted from diesel engines by 80 per cent, while also tightening NOx emission requirements. The main change contained within the Euro 6 standard is the further reduction of NOx emissions from diesel engines to a level closer to that currently required of petrol engines. Also new is a standard for particle numbers (PN). The number limit will prevent the possibility that the tougher mass limit for PM is met using technologies (such as "open filters") that would enable a high number of ultra-fine particles to pass.

Prior to Euro 5, particulate matter from petrol engines was not regulated, as emissions are low compared to diesel engines. However, some direct-injection petrol engines can create PM emissions of a level comparable to diesel engines, and under the Euro 5 and 6 standards the same limit of 5 mg/km is imposed on both diesel and direct-injection petrol engines.

The Commission had originally proposed a Euro 5 limit of 200 mg/km for NOx emissions from diesel engines, which was reduced to 180 mg/km in negotiations between the Parliament and Council. However, this level of reduction limit does generally not require the use of NOx after-treatment technologies. Further reductions to 80 mg/km under the Euro 6 standard in 2014 will likely require such technologies to be fitted.

The future Euro 6 standard is still substantially weaker than standards currently in force in the United States. There, the so-called Tier II standards limit fleet average NOx emissions close to 40 mg/km (70 mg/mile) for both diesel and petrol engines. The Tier II standards have already been in force for several years in California and several other states.

Under the current framework, large personal vehicles with a weight of over 2.5 tonnes – that is, sports utility vehicles (SUVs) – are subject to the less strict rules applicable to vans. While the Commission had proposed to close this concession under the Euro 5 standard, a compromise between the Parliament and the Ministers extended it until September 2012. From this date, SUVs are subject to the same limits as other personal vehicles.

Table 2. Emission standards for heavy-duty vehicles.

	NOx (g/kWh)		THC [1] (g/kWh)	NMHC [2] (g/kWh)	PM (mg/kWh)		PN (#/kWh)	
	Diesel	Gas/Petrol	Diesel	Gas/Petrol	Diesel	Gas/Petrol	Diesel	Gas/Petrol
Euro I 1992	8.0	-	1.23	-	360/612	-	-	-
Euro II a 1996.10	7.0	-	1.1	-	250	-	-	-
Euro II b1998.10	7.0	-	1.1	-	150	-	-	-
Euro III 2000.10	5.0 [3]	5.0	0.66 [4]	0.78	100/160 [5]	-	-	-
Euro IV 2005.10	3.5 [3]	3.5	0.46 [4]	0.55	20/30 [5]	-	-	-
Euro V 2008.10	2.0 [3]	2.0	0.46 [4]	0.55	20/30 [5]	30	-	-
Euro VI 2013.01	0.4/0.46 [6]	0.46	0.13/0.16 [6]	0.16	10/10 [6]	10	$6x10^{11}/8x10^{11}$ [6]	-

[1] Total hydrocarbons (methane included); [2] Non-methane hydrocarbons; [3] Both ESC and ETC test cycle; [4] ESC test cycle only; [5] ESC and ETC test cycle respectively; [6] WHTC and WHSC test cycle respectively

New legislation on durability was introduced along with the Euro 3 and 4 standards, making manufacturers responsible for the emissions from light vehicles for a period of five years or 80,000 km (Euro 3) and five years or 100,000 km (Euro 4), whichever comes first. Euro 5 and 6 standards maintain the five year or 100,000 km durability requirement for 'in-service conformity', but require an extended durability of five years or 160,000 km in the durability testing of pollution control devices for type approval.

Euro standards for heavy vehicles

The first EU directive to regulate emissions from heavy vehicles, i.e. road vehicles heavier than 3.5 tonnes, came in 1988 (88/77/EEC). Before that there had been a common standard within the UN Economic Commission for Europe (ECE R49).

The Euro I standards for medium and heavy engines were introduced in 1992–93 (91/542/EC). The same directive also laid down standards for Euro II, which took effect in 1995–96. Another directive (1999/96/EC) was adopted in 1999 giving standards for Euro III (2000), IV (2005) and V (2008). In 2013 the Euro VI standard (defined in regulation 595/2009) will be put in to effect.

The way in which the emission standards for heavy road vehicles in the EU have been stiffened over the years is shown in table 2. There are different standards for compression ignition engines (diesels) and positive ignition engines (gas and petrol), however among heavy-duty vehicles there is only a tiny fraction that does not run on diesel. The standards for heavy-duty vehicles are defined by energy output (g/kWh) and cannot be directly compared with the standards for light vehicles where standards are defined by distance.

The present Euro V standard differs from Euro IV in its stricter emission requirement for NOx. Euro VI is a step forward towards global harmonisation since the limit values are similar to those of the United States, where the limit for NOx is 0.27 g/kWh and the limit for PM is 13 mg/kWh.

The Euro VI regulation also includes an ammonia (NH_3) concentration limit of 10 parts per million (ppm) for both compression ignition and positive ignition engines. In June 2011 a particle number (PN) limit was defined for diesels, in addition to the mass limit (582/2011). A corresponding limit for positive ignition engines is yet to be defined.

The Commission also have the right to define a maximum limit for the NO_2 component of NOx emissions in future implementing regulation. In "traditional" diesel engines the NO_2 content in the total NOx emissions is about 5 per cent. Modern engines may, however, bring this share up to 50 per cent, strongly depending on the technology used.

CO_2 standards

Within the context of the EU's commitment to reducing greenhouse gas emissions, limits on CO_2 emissions from cars have long been discussed. As early as 1994, Angela Merkel, then environment minister in Germany, proposed to cap car CO_2 emissions at 120 g/km from 2005.[3]

However, the first binding limits for CO_2 emissions from vehicles were only agreed in 2009, when the EU set a legally binding CO_2 standard for new cars (443/2009). In May 2011 a similar EU legislation for vans was passed (510/2011).

Since there is currently no after-treatment technology that can reduce CO_2 emissions from road vehicles, the standards can also be seen as fuel efficiency standards.

CO_2 standard for passenger cars

The CO_2 emission standard for cars is designed to ensure that the average car sold in Europe by 2015 should emit no more than 130 g/km of CO_2, and by 2020 no more than 95 g/km. In 2013 the EU will review how the 2020 target should be reached. The Commission also considers targets beyond 2020, including a target of 70 g/km by 2025 as suggested by the European Parliament. Transport & Environment (T&E) believes that this is not enough and argues for a 80 g/km target by 2020 to be tightened to 60 g/km by 2025.

The core of the present regulation is a linear limit curve, where the weight of the car is a variable. The equation for the line has been set so that the fleet average for all new cars registered in the EU will be 130g/km. The slope of the line is designed so that greater improvements are required for heavier cars than lighter ones. This is supposed to encourage an increase in production of lighter, more fuel-efficient cars.

3 Howarth, David, (2009) Greening the internal market in a difficult economic climate, The Journal of Common Market Studies, Volume 47 pp133-140

However the weight-based model has been criticised for inhibiting producers from developing lighter cars with the same capacity as existing heavy models. Instead, a footprint (track width times wheelbase) model is proposed in which the area between the wheels should determine the emissions allowed.[4]

A single manufacturer does not need to meet the requirements itself but can instead team up and form a pool with other manufacturers who must then jointly meet the emission targets. Manufacturers that sell less than 10,000 vehicles per year and who cannot or do not wish to join a pool can instead apply to the Commission for an individual target

From 2012 until 2015 there will be a period of phasing in the new legislation. In 2012 the 130 g/km limit will apply to 65 per cent of all cars a manufacturer or a pool of manufacturers produces, in 2013 to 75 per cent, in 2014 to 80 per cent, and in 2015 the regulation will apply to all new cars.

In addition, fines for non-compliance will also be phased in. Manufacturers will incur a penalty payment of €5 for the first g/km of exceedance, rising to €15 for the second g/km, €25 for the third g/km, and €95 for each subsequent g/km. Only from 2019 onwards, will the penalty be levied at €95 from the first gram.

The agreement also allows up to 7 g/km of credit to be given for 'eco-innovations' that produce emission reductions not currently identified by vehicle testing procedures, such as LED lights or solar sunroofs.

According to the European Environment Agency, CO_2 emissions from new cars sold in the EU in 2010 averaged 140.3 g/km, which is 5.4 g/km less than the previous year.[5] Critics of the resulting regulation believe that a majority of this decrease is due to changes that would happen anyway and that car manufacturers will be technologically capable of meeting the 130 g/km target well before the 2015 deadline. It was on the basis of technological limitations that the industry had earlier successfully lobbied to weaken the regulation.

CO_2 standard for vans

This category of vehicles includes vans and car-derived vans weighing up to 3.5 tonnes that are being used to carry goods, and which weigh less than 2610 kg when empty. These account for around 12 per cent of the market for light-duty vehicles. In 2007 the average van sold emitted 203 g/km.

The standard will ensure that CO_2 emissions from new sales average 175 g/km by 2017, by using a similar limit curve as the one for passenger cars. The regulation is phased in so that by 2014 70 per cent of each manufacturer's newly registered vans must comply with the limit value curve. This will rise to 75 per cent in 2015, 80 per cent in 2016, and 100 per cent from 2017 onwards. A long-term target of 147 g/km is set for 2020 (subject to review in 2013). According to research commissioned by T&E the target for 2017 can be achieved by simply ending the trend towards more powerful engines and returning to the engine power levels of 1997.[6] They argue that a target of 125 g/km by 2020 would be both feasable and more in line with the present target for passenger cars.

As for passenger cars it is possible for two or more van manufacturers to join a common pool and reach the target jointly. Manufacturers that sell fewer than 22,000 vehicles per year and do not wish to join a pool can apply to the Commission for an individual target.

The same arrangement for 'eco-innovations' as in the passenger car regulations applies to vans. For vans there is also a special credit construction for vehicles with emissions below 50 g/km. They will be counted as 3.5 vehicles in 2014 and 2015, 2.5 in 2016 and 1.5 vehicles in 2017. Manufacturers will be able to claim this 'super credit' for a maximum of 25,000 vans over the 2014-17 period. The penalties for exceedance are the same as for passenger cars, including the penalty discounts between 2014 and 2018.

Fuels/fuel quality

The Directive on the quality of petrol and diesel fuels was passed in 1998 (98/70/EC) and sets maximum levels on sulphur, lead and aromatics allowed in fuels. In the latest amendment (2009/30/EC) the maximum sulphur content permitted in fuels was set at 10 parts per million (ppm) – a level that was a technical prerequisite for the use of the PM filters needed to meet the stiffer requirements for particulate matter in the Euro 5 standard.

Fuel suppliers are also required to gradually reduce life cycle greenhouse gas emissions by at least 6 per cent per unit of energy from fuel and energy supplied by the end of 2020 compared to the average levels in 2010. This reduction should be achieved through the use of biofuels, alternative fuels and reductions in flaring and venting at production sites.

Further Information

The European Commission Environment:
http://ec.europa.eu/environment/air/transport/road.htm

The European Commission Climate Action:
http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm

The European Commission Enterprise and Industry:
http://ec.europa.eu/enterprise/sectors/automotive/environment/index_en.htm

The European Union law
http://eur-lex.europa.eu/

Transport & Environment:
http://www.transportenvironment.org/

Articles in Acid News:
http://www.airclim.org/acidnews/

4 How clean are Europe's cars? Transport & Environment September 2011 *http://www.transportenvironment.org/Publications/prep_hand_out/lid/653*

5 Monitoring the CO_2 emissions from new passenger cars in the EU: summary of data for 2010, EEA, June 2011 *http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission*

6 Potential CO_2 reduction from optimal engine sizing for light commercial vehicles, TNO, June 2010, *http://www.transportenvironment.org/Publications/prep_hand_out/lid/586*

Box: Emission control technology for vehicles

Petrol-driven passenger cars

A petrol engine without emission control produces large emissions of nitrogen oxides and unburnt hydrocarbons. The technology that manufacturers have used to meet stiffer emission requirements is the three-way catalytic converter. This consists of a ceramic material with microscopically small channels, coated with a very thin film of precious metals. As the exhaust gases pass through the converter the hydrocarbons and carbon monoxide are oxidised by the oxygen that is released when the nitrogen oxides are reduced to nitrogen (N_2). The three-way catalytic converter has been fitted to all petrol passenger cars sold in the EU since the start of the 1990s and has become increasingly efficient as emission requirements have become stricter. The biggest problem is during cold starts, since a certain temperature (300-400°C) has to be reached before the catalytic process starts to work. Some models have pre-heating systems, while others collect some of the initial exhaust gases and heat them before they pass through the catalytic converter. In the case of petrol engines that use an excess of air (known as lean-burn technology) the three-way catalytic converter has no effect on emissions of NOx. Some manufacturers use a NOx trap (see Diesel-driven passenger cars below) to meet the standards. Petrol vehicles with direct injection (GDI, FSI, SCi, etc.) produce relatively high emissions of PM, which means that these may require special PM reduction as emission requirements are stiffened (see Diesel-driven passenger cars below).

Diesel-driven passenger cars

The biggest air pollution problems associated with diesel vehicles are emissions of NOx and PM, both of which are higher than for petrol vehicles.

NOx. Because a diesel engine works with an excess of air the three-way catalytic converter cannot be used to reduce emissions of NOx. Instead Exhaust Gas Recirculation (EGR) has been the most widely used technology to reduce NOx emissions from diesel engines. The EGR technology implies that some of the exhaust gases are recirculated through the combustion chamber. The addition of exhaust fumes lowers the combustion temperature and reduces NOx formation. Less effective combustion and increased soot production are some disadvantages with the EGR technology. There is also a limit to the extent that the EGR technology can reduce NOx (around 35 per cent), which means that further treatment of exhaust gases is likely to be necessary in order to meet future standards.

One further treatment method is to use a NOx adsorber, also known as a NOx trap. It consists most commonly of the mineral zeolite, which adsorbs NO and NO_2 molecules. After a few minutes the material gets saturated and loses its ability to trap more NOx, so there is a need for periodic regeneration. One regeneration technique is to run combustion with excess diesel for some seconds. The CO formed during this period will quite easily reduce the trapped NOx to N_2. This method has been in commercial use since 2008.

Another method – although mainly applied to heavy vehicles – is selective catalytic reduction (SCR). This involves reducing the nitrogen oxides to nitrogen gas in a catalytic converter with the aid of ammonia (injected as urea). The reduction efficiency approaches 80–90 per cent. Disadvantages include the added operating cost of using urea, the possibility of increased ammonia emissions and the loss of effect when the urea tank is empty. Some questions also exist regarding the durability of the technology. One advantage is that higher levels of NOx can be permitted during the combustion process, which can consequently be better optimised for low fuel consumption.

PM. The formation of particulates can be reduced to some extent by modifying the combustion process. Smaller engines could meet Euro 4 requirements in this way. But with the stiffened emission requirements of Euro 5, particulate filters are required for all diesel engines. They consist of a ceramic matrix of silicon carbide, perforated with microscopic channels. As the exhaust gases pass through, a large proportion of particulates (90–99 per cent) stick to the walls of these channels. The trapping of particulates means that the channels become blocked, and the filter therefore has to be raised to a high temperature at regular intervals to burn off the particulates. Various methods have been developed to achieve this combustion, including a brief additional injection of fuel and a catalytic substance that reduces the temperature required. One requirement for low particulate emissions is a fuel with low sulphur content.

Heavy vehicles

Practically all heavy road vehicles have diesel engines. In common with diesel cars, the emissions that are most important to reduce are NOx and particulates. In the case of NOx the Euro V requirement for 2008 (max. 2 g/kWh) has in practice compelled the use of SCR (see above) on all new heavy vehicles.

Particulate reduction by means of filters is easier to solve for heavy diesel vehicles than for light ones, since heavier vehicles have a higher exhaust temperature. This makes the critical phase – burning off particulates from the filter – easier to achieve. A particulate filter is often combined with an oxidation catalytic converter that reduces the content of carbon monoxide and hydrocarbons in the exhaust gases.

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